# EFFECTS OF MANAGEMENT ACTIVITIES AND DOMINANT SPECIES TYPE ON PEST-CAUSED MORTALITY LOSSES IN TRUE FIR ON THE FREMONT AND OCHOCO NATIONAL FORESTS

FOREST PEST MANAGEMENT

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# EFFECTS OF MANAGEMENT ACTIVITIES AND DOMINANT SPECIES TYPE ON PEST-CAUSED MORTALITY LOSSES IN TRUE FIR ON THE FREMONT AND OCHOCO NATIONAL FORESTS

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## ABSTRACT

One hundred and ninety-two stands in six stand composition/past management strata on the Fremont and Ochoco National Forests were surveyed to evaluate differences in amounts of pest-caused true fir mortality. Surveyed stands with true fir overstories had significantly more fir mortality than those with pine overstories, and most true fir mortality in the latter type of stand was not pest-caused. Among surveyed stands with true fir overstories on the Ochoco National Forest, particularly large amounts of mortality (23 percent of the true firs dead), were observed in unentered stands. Most mortality in such stands was caused by laminated root rot and fir engraver beetles. Losses were less but still high in stands that had one harvest entry (15 percent of the trees dead) or multiple harvest entries (9 percent of the trees dead). Losses in these stands were caused by annosus root rot, Armillaria root rot, stem decays, and fir engraver beetles. Among surveyed stands with true fir overstories on the Fremont National Forest, by far the greatest amount of mortality (23 percent of all true firs dead), was found in stands that had multiple harvest entries. Significantly less mortality was observed in stands that had one or no entries (6 and 2 percent of the true firs dead, respectively). Most true fir mortality on the Fremont was caused by annosus root rot acting alone or with fir engraver beetles. The great amount of annosus root rot in entered stands on both Forests reflects the efficient use of stumps as infection courts by Fomes annosus and shows how this pathogen can become a serious threat in managed stands.

## INTRODUCTION

White fir (Abies concolor) and grand fir (A. grandis) are closely related species that are major components of many East Side forest stands in the Pacific Northwest. They are prolific seeders, establish themselves readily on diverse sites, and are rapid growers. Due to fire exclusion and the practice of partial cutting, the true firs have increased dramatically at the expense of the more fire-tolerant, shade-intolerant ponderosa pine (Pinus ponderosa) in many stands once dominated by that species. As their numbers and value have burgeoned, white and grand firs have come to represent an increasingly important resource to forest managers.

Unfortunately, the true firs also are very prone to growth and mortality losses caused by forest pests. Root rots, stem decays, and dwarf mistletoes, as well as fir engraver beetles (Scolytus ventralis), budworms (Choristoneura occidentalis and C. viridis), and Douglas-fir tussock moth (Orgyia pseudotsugata) can damage these species seriously.

Of particular concern to forest pathologists is an apparent increase in mortality of true firs in southeastern Oregon attributed to fir engraver beetles and the root pathogens Fomes annosus, Phellinus weirii, and Armillaria mellea. Observations suggest that stands with histories of repeated selective harvests exhibit the greatest amount of root disease-bark beetle damage, but data to confirm or disprove this contention have been lacking. Objectives of the present evaluation were to: (1) assess the value of low-level aerial photography for detecting pest-caused losses in stands with true fir components on the Ochoco and Fremont National Forests, and (2) measure losses in such stands to ascertain how stand character and past management regimes affect levels of damage.

## METHODS

Sample Stand Selection - On each of the two National Forests, 96 stands were selected. Each group of 96 included 16 stands in six species composition/past management regime strata. Species composition categories used were: (1) stands with true fir as a major overstory species (20 percent or more of dominant or codominant overstory trees), and (2) stands with ponderosa pine as the major overstory species with true fir as a component of the understory. Within each of these species composition categories, three past management levels were investigated: (1) unentered stands (no management), (2) stands that had one entry prior to 1978, and (3) stands that had been entered at least twice prior to 1978. Entries were one of the following types of harvest: partial removal, sanitation, selection, or commercial thinning. Any stands that had been clearcut or clearcut with seed trees reserved were not sampled. All candidate stands were listed using the Region 6 TRI System, and selection of stands within species composition/past management regime strata was done using a random number table. Following selection, stands that were less than 100 acres in size were grouped with adjacent stands that were of the same strata until a block of cells totaling at least 100 acres was formed. When a group of cells could not be built to meet this size criterion, the original selection was discarded and a new one made.

Aerial Photography, Interpretation and Ground Truth Determination - In July 1983, all selected sample stands were photographed from the Forest Pest Management Method Application Group's Beechcraft Queenair D-80 while flying at 4100 feet above the ground. Photos were taken with a Ziess RMK 21-23 camera (focal length 8-1/4 inches) using true color, Ektachrome SO-397 film. Three 9x9-inch transparencies (a stereo triplet) were taken of each stand. The photo plot, a 3.96-inch-square representing 90 acres on the ground, was located in the center of the photo with the best coverage of the unit.

Of the 16 stands in each species composition/past management regime strata for the two Forests, five were selected randomly for ground checking. Photo plots for ground check stands were divided into a grid of 25 subplots, each 3.6 acres in area (396 feet square on the ground). Two subplots were selected randomly for ground checking from each sample photo plot.

All photo plots were interpreted in the office. Photos were inspected at 10X magnification under an Old Delft scanning stereoscope. All visible dead trees were tallied and an attempt was made to identify them by species. Data for subplots chosen for ground checking were kept separate from those for the main body of the photo plots, so that they could be compared with cruise data.

Ground plots were located in the field in September and October 1983, on the precise area delineated by the photo subplots. Each area was 100 percent cruised for dead trees. Regressions between ground cruise and photo interpretation data were calculated to determine the accuracy of interpretation results and to develop equations for projecting losses in stands not ground checked.

Stand Examinations - Within each stand selected for photo plot ground checking, a 10-point stand examination also was done. Points were located at 2-chain intervals along two transects 5 chains apart with the first line originating from the corner of the photo ground check subplot nearest the center of the main photo area. At each point, a variable radius plot (BAF 40) and a fixed-area plot (1/100-acre) were established. All trees in variable radius plots were tallied by species, DBH, and condition (live healthy, live symptomatic, recent kill, snag, stub, or down dead). Trees less than 6 inches DBH but greater than 1 foot in height in fixed-area plots were tallied by species and condition. Crowns and stems of all trees in either kind of plot were examined for evidence of pests, and bark was removed from stems of dead trees to determine identity of subcortical insects infesting them. Dead and symptomatic trees had roots exposed for root disease diagnosis. A subsample of trees identified as being infected by root pathogens, as well as those for which no field identifications could be made, had root samples with stain or decay returned to the laboratory for tissue culturing on 2 percent malt agar and selective medium. Distances from all dead or diseased "in" trees to the nearest stump (within 50 feet) were recorded. Stumps of trees that would have been in the variable radius plots if not cut were tallied by diameter class and examined for evidence of colonization by pathogenic fungi. Finally, in each variable radius plot, the "in" true fir closest to the plot center had all data collected necessary for use in the stem decay infection and decay equations developed by Filip et al.*

Data collected in stand examinations were used to construct stand tables for the six stand composition/past management regime strata on each Forest. Stand tables were segregated by tree condition and pests affecting trees. Thus, mean total mortality and amount of mortality caused by each pest or mortality-causing factor could be compared among strata. Differences were tested using chi-square analyses and factorial analyses of variance.

*G. M. Filip, P. E. Aho, and M. R. Wiitala. 1983 Indian paint fungus: a method for recognizing and reducing hazard in advanced grand and white fir regeneration in eastern Oregon and Washington. USDA Forest Service, Pacific Northwest Region. 18 pp

## RESULTS AND DISCUSSION

### I. Usefulness of Low Level Aerial Photography for Detecting Mortality in Stands Containing True Fir

Regression analyses (summarized in Table 1) indicate that interpretation of low-level (1:6000) color aerial photos could be used to estimate accurately total tree mortality and true fir mortality in many of the types of stands surveyed in this evaluation. Regressions between interpreted results and 100 percent ground cruises of dead trees 6 inches or greater DBH yielded high $R^2$ values (0.4 - 0.9) for all pine overstory stands and unentered stands with true fir overstories. However $R^2$'s for entered stands with true fir overstories were low (0.2 - 0.3). We feel that the reasons for poorer correlations in entered true fir stands were the large variability in amount of mortality among such stands and the inconsistent relationship between number of standing dead and down dead trees. Both were, to a great degree, the result of the pest complexes occurring in the stands.

The most common root disease in most entered fir stands was annosus root rot, and a major part of all mortality in such stands was caused by this disease alone or fir engraver beetles acting with annosus root rot. We found that amount of mortality with F. annosus was more a function of length of time since harvesting than number of harvest entries. Thus, variability in amount of mortality within the entered stand strata used in this evaluation was great because time elapsed since harvest varied considerably within each category. Also, trees infected by F. annosus tended to be windthrown or broken off to form stubs more frequently than trees affected by other pests. Eighty percent of the dead true firs infected by F. annosus in our 100 percent ground cruises were down or broken off at a height of less than 20 feet, while for all other pests, only 60 percent of the dead trees fit this description. More importantly, many annosus root rot pockets, especially in stands with the longest times elapsed between entry and our survey, contained no standing dead trees, while most infection centers of other root disease organisms did. Since stubs and dead down trees were not detected readily on aerial photos, it was difficult to assess accurately the amount of mortality that they represented unless they occurred and exhibited a consistent relationship with standing dead trees.

Ground surveys are, of course, necessary complements to any aerial surveys. In an evaluation of the type undertaken here, they were necessary to establish total stocking and specific causes of mortality for all surveyed strata. Our results suggest further that intensive ground surveys are required to determine accurately the amount of mortality in entered fir stands with F. annosus.

Photo interpretation results from all 192 photographed stands were expanded, using the regression equations calculated for ground checked stands, and amount of fir mortality was expressed as a percent of the total stocking obtained from stand examinations for all strata (Table 2). When this was done, photo interpretation results were quite similar to stand examination results for strata that exhibited high $R^2$ values. For strata that exhibited low $R^2$ values, mortality trends were similar, but photo interpretation results were lower than stand examination results. The remainder of this analysis will be based on stand examination results.

## II True Fir Mortality Losses as Affected by National Forest, Stand Composition, and Past Management History

Amount and causes of true fir mortality differed among surveyed stands in different species composition-past management strata and also between the two National Forests. Total stocking, proportion composed of true firs, amount of true fir mortality, and causes of true fir death are summarized by Forest, stand type, and management strata in Table 2. More detailed data by size class for all tree species are given in the composite stand tables in Appendix A. In general, true firs suffered considerably higher levels of mortality than other tree species in surveyed stands. The exceptions involved ponderosa and lodgepole pines in unmanaged, overstocked stands with pine overstories where mountain and western pine beetles were infesting large numbers of trees (Tables A1 and 7).

On both the Ochoco and Fremont National Forests, true fir mortality was significantly greater ($P=0.05$) in stands with true fir in the overstories than in those with pine overstories. In stands with true fir overstories, most true fir mortality was caused by diseases or insects, while in stands with pine-dominated overstories, a major part of the true fir mortality was caused by logging equipment physically pushing trees over during harvest operations. This was especially noticeable on the Fremont National Forest.

Among stands with fir overstories on the Ochoco National Forest, the most mortality, 23 percent of all true firs dead (containing 29 percent of the basal area) was observed in unentered stands. Losses were less but still high in entered stands, an average of 15 percent (containing 22 percent of the basal area) in stands entered once, and an average of 9 percent (containing 20 percent of the basal area) in stands entered more than once.

Among stands with fir overstories on the Fremont National Forest, levels of mortality were especially great in stands that had experienced multiple harvest entries. An average of 23 percent of the true fir (accounting for 24 percent of the basal area) in these stands was dead. Mortality was significantly less ($P=0.05$) in once-entered and unentered stands where it averaged 6 percent (containing 15 percent of the basal area) and 2 percent (containing 6 percent of the basal area), respectively.

The observed differences in distribution of mortality losses between the Forests is due largely to differences in the pests that occur in them. Pests encountered in our evaluation and their roles in causing true fir mortality were as follows:

### Annosus Root Rot

Our survey revealed annosus root rot, caused by the fungus *F. annosus*, to be the most common and damaging disease of true firs on the Fremont National Forest, where it was associated with more than 70 percent of all mortality observed (Table 2), affected trees in virtually all size classes (Tables A 7-12), and occurred wherever there was true fir. Annosus root rot was less widely distributed and damaging on the Ochoco National Forest (Tables 2 and A 1-6). There it accounted for about 10 percent of the observed true fir mortality and was encountered most frequently in the southern part of the Forest.

On both Forests, annosus root rot was significantly more likely to occur in stands that had true fir overstories than pine overstories (P=0.01). It was significantly more likely to occur (P=0.05) and caused significantly more mortality (P=0.01) in stands that had experienced harvest entries than in unentered stands, and it caused by far the greatest amount of mortality in stands that had been entered more than once. Within the multiple-entry class, those stands in which the longest time had elapsed since the initial harvest exhibited the greatest amount of annosus root rot (for example, 69 percent of all true fir was infected in a stand on the Lakeview District, Fremont National Forest, first logged in 1938).

Annosus root rot was identified tentatively on dead or declining true firs that exhibited a brown-to-reddish stain with uneven margins (Figure 1) or a white, stringy to somewhat laminated decay with black flecks (Figure 2) in the roots or root collar. Identity of the causal fungus was confirmed if diagnostic asexual fruiting structures (Oediocephalum) were formed when stained or decayed wood samples were cultured on media or incubated in moist newspaper.

Fomes annosus spreads overland by windborne spores. Conks (Figure 3), usually found in hollow stumps, produce large numbers of spores that can be blown long distances. If spores land on freshly-cut stump surfaces or recently created wounds, they germinate and the fungus colonizes the stump or tree. It then grows through the root system and, hence, across grafts and contacts into roots of nearby healthy trees. Infection centers (Figure 4) develop as the disease progressively spreads across tree roots into the surrounding stand. Infection results in tree decline, growth deceleration and, eventually, death. Fir engraver beetles frequently infest and help to kill annosus root rot-weakened trees. Fir engravers were found on 22 percent of the F. annosus-infected trees encountered in our survey.

The large amount of annosus root rot damage observed in stands with multiple stand entries (and thus the largest numbers of stumps and stumps that had existed for the longest time since cutting) undoubtedly reflects F annosus' efficient use of stumps as infection courts. We found that 5 percent of the true fir stumps in surveyed stands on the Ochoco and 45 percent of those on the Fremont National Forest were visibly colonized by F. annosus. Mortality caused by annosus root rot almost always occurred in firs within 20 to 40 feet of old, infected true fir stumps, and virtually all stumps that served as infection foci were 18 inches or greater in diameter. Distances from stumps to current mortality indicated a radial spread rate across root systems of between 1 and 2 feet per year. The greater amount of annosus root rot observed on the Fremont National Forest than on the Ochoco probably is due to differences in harvest histories. Widespread cutting of large white firs, and hence creation of many stump infection courts, apparently began at least a decade earlier on the Fremont than on the Ochoco. A few isolated F. annosus infections that appeared to have originated through wounds were observed on both Forests. Some were seen even in unentered stands on the Fremont.

Fomes annosus is known to affect several other tree species besides the true firs in southeastern Oregon. Ponderosa pine and western juniper are prone to infection in some areas. However, it is thought that the fungus

has different strains, one of which infects the true firs and not the other species. Our results strongly support this theory. There was no evidence of annosus root rot-caused true fir mortality in the vicinity of stumps of other tree species and no mortality whatsoever of other species around obviously F. annosus-infected true fir stumps in our sample stands.

## Laminated Root Rot

Laminated root rot, caused by the fungus Phellinus weirii, was the most common root disease of true firs found in the northern part of the Ochoco National Forest. The southern boundary of the range of this pathogen in the survey area is the Crooked River Valley, so it was not encountered in the Maury Mountains or the Snow Mountain Ranger District. Notwithstanding, it was responsible for over 40 percent of the true fir mortality encountered in Ochoco stands (Table 2). Trees in all size classes were affected (Table A4). The entire Fremont National Forest is outside of the range of P. weirii.

In our sample, laminated root rot was found only in relatively high elevation (over 5600 feet) stands with true fir overstories that had not had harvest entries. It was, however, observed in entered stands that had not been selected for sampling. In other parts of the Pacific Northwest, P. weirii is extremely damaging in infected areas that have been harvested and regenerated with susceptible tree species.

Laminated root rot was identified by the typical laminated wood decay that separates readily at the growth rings (Figure 5), the grayish, crusty ectotrophic mycelia that the causal fungus forms on root bark, and the diagnostic reddish, whiskery setal hyphae (Figure 6) that occur on the ectotrophic mycelium and between the layers of rotted wood. Presence of many windthrown trees with root systems completely decayed to form "root balls" (Figure 7) commonly was associated with occurrence of laminated root rot.

Phellinus weirii rarely, if ever, spreads by spores. Rather, it causes a disease of the site and is particularly adept at persisting from tree generation to generation in already-infected areas. The fungus can survive in large roots of stumps, snags, or stubs for 50 years or more and infects new hosts that become established nearby by mycelium spreading across root grafts and contacts. Infection centers increase in size due to spread from tree to tree along roots at a rate of about 1 foot per year. The very large sizes of most infected areas observed on the Ochoco indicate long-term residency by P. weirii. Among highly susceptible tree species such as the true firs, infection by P. weirii results in decline and death or windthrow. True firs weakened by P. weirii commonly are infested by fir engraver beetles. Fir engravers were found on 53 percent of the P. weirii-infected firs encountered in our survey.

Other conifer species are affected by P. weirii to varying degrees. Douglas-fir, like the true firs, is highly susceptible. It is readily infected and killed by the pathogen. Engelmann spruce and western larch are intermediately susceptible. They are often infected but usually are not killed by P. weirii. The pines are tolerant or resistant. They are rarely infected and almost never killed by the pathogen.

## Armillaria Root Rot

Armillaria root rot, caused by A. mellea, was less damaging overall than annosus or laminated root rot, but was distributed widely on both the Ochoco and Fremont National Forests. It was associated with about 10 percent of the true fir mortality on each Forest (Table 2) and affected trees in all size classes (Tables A4, 5, 8, 10-12).

On both Forests, Armillaria root rot was significantly (P=0.05) more likely to infect true fir in stands with true fir overstories than in those with pine overstories. No significant differences were found in likelihood of A. mellea occurrence or amount of mortality caused by Armillaria root rot among different past entry categories.

Armillaria root rot was identified by the yellow spongy decay with numerous zone lines that it causes in roots and butts of affected trees, by the presence of rhizomorphs (shoestring-like infective structures), and especially by the diagnostic white mycelial fans (Figure 8) formed by the causal fungus under bark at the bases of infected trees.

Armillaria mellea is a very efficient saprophyte that survives in stumps, roots, and other buried woody material virtually everywhere. The fungus can infect living trees across root contacts or by growing short distances through soil. Under normal conditions, A. mellea is a rather weak pathogen that mainly infects and helps to kill stressed, overmature, or injured trees. Sometimes, however, the fungus can be very aggressive, forming large, active infection centers (Figure 9). It is believed that particularly pathogenic strains of the fungus are reponsible for this type of damage. Much of the Armillaria root rot-caused mortality observed in our survey involved individual, widely-scattered trees, but intense areas of infection were observed, especially in the southern part of the Ochoco. Armillaria mellea frequently is associated with other pathogens. In our survey, it was also found infecting trees with annosus root rot and Indian paint fungus. Fir engraver beetles commonly infest A. mellea-infected true fir and, in our survey, were found on 37 percent of the trees with Armillaria root rot.

Armillaria mellea potentially can infect most conifer species. Results of our surveys show, however, that on the Ochoco and Fremont National Forests, it mainly occurs and is most damaging on the true firs.

## Fir Engraver Beetles

Fir engraver beetles (S. ventralis) were involved in 39 percent of the true fir mortality on the Ochoco National Forest and 12 percent of that on the Fremont (Tables 2 and A2-6,8, and 10-12). Fir engravers were associated with mortality in all types of fir stands. They sometimes acted as primary tree killers, but their main role was infesting trees previously infected by root or stem pathogens. In our survey, 86 percent of the fir engraver-infested trees were infected by F. annosus, P. weirii, A. mellea, or Indian paint fungus.

Fir engraver beetles were identified on dead and dying true firs by their characteristic galleries (Figure 10) under the bark. Adult galleries are oriented horizontally, deeply scoured with a central nuptial chamber, and often slightly bowed at the ends. Larval galleries radiate up and down the stem from the adult gallery.

Fir engraver beetles exhibit a well-developed ability to locate and infest weakened or stressed trees. Besides diseased trees, they were mostly found in our survey infesting trees in entered stands that had been injured during logging activities. They also were encountered in areas where drainage changes had caused flooding.

## Stem Decay Fungi

Stem decay fungi, mainly the Indian paint fungus (Echinodontium tinctorium) and yellow cap fungus (Pholiota limonella) but including many others, commonly infected true firs in surveyed stands. Stem decay fungi contributed to some tree mortality through trunk breaks. Breakage mostly occurred in large, old trees. On the Ochoco 6 percent and on the Fremont 1 percent of true fir mortality was caused by decay-induced breaks (Tables A 3-6, 10 and 11). By far the most damaging role of stem decay fungi, however, is that of causing internal decay and degrade in living trees (Figure 11). In our survey, using equations developed by Filip et al, we estimated that 25 percent of the true firs in surveyed stands on the Ochoco and 34 percent of those on the Fremont National Forest were infected by stem decay fungi (Table 2). Estimated current amount of board-foot volume decayed in true firs averaged 5 percent of the total in Ochoco stands and 13 percent in stands on the Fremont (Table 3).

Amount of infection by stem decay fungi and estimated amount of decay in true firs were significantly greater ($P=0.05$) in stands with true fir overstories than in stands with pine-dominated overstories. Entered stands tended to have more infection and more volume decayed than unentered stands although differences were not statistically significant, and some unentered stands, especially on the Fremont, had considerable amounts of decay in very old trees.

Occurrence of stem decays can sometimes be detected by presence of conks (Figure 12) or mushrooms on affected trees, but such fruiting bodies often are not formed until many years after infection when decay is very advanced. Overmature trees, trees that have been suppressed for many years, and trees with poor live crown ratios are more likely to be infected by stem decay fungi than young, vigorous trees. Also, true firs with wounds (Figure 13) have a particularly high probability of being infected and containing advanced decay. Wounding activates dormant Indian paint fungus infections and creates infection courts for other decay fungi. The equations developed by Filip et al were based on numerous dissections of randomly-selected true firs and are very useful for predicting amounts of infection and decay on a stand basis.

The true firs, as nonresinous, relatively thin-barked species, are much more susceptible to infection by stem decay fungi and rapid decay development than are other species of conifers on the Ochoco and Fremont National

Forests. Management of unthrifty, suppressed understories and maintenance of older stands with many wounded trees resulting from lack of care during harvest entries greatly favor high losses due to decay in true firs.

### Other Pests

A number of other pests of true firs that did not cause measurable amounts of tree mortality were encountered in our survey. These included true fir dwarf mistletoe (Arceuthobium abietinum), fir broom rust (caused by Melampsorella caryophyllacearum), fir needle cast (caused by Lirula abietis-concoloris), western spruce budworm (C. occidentalis), and Modoc budworm (C. viridis). Impacts of these pests mostly involve growth loss and could not be quantified in this evaluation.

## MANAGEMENT IMPLICATIONS AND RECOMMENDATIONS

Results of our evaluation confirm previously held suspicions that true firs on the Ochoco and Fremont National Forests suffer severe mortality losses due to diseases and insects. They also show that pest activity is affected greatly by the type of management practiced in a stand. Silviculturists need to carefully consider existing and potential pest problems when preparing prescriptions for the true firs. Wherever they are a desired species, true firs must be managed, not taken for granted, and they must be managed with care. Specific recommendations are as follows:

(1) Favor other tree species over true firs in stands affected by annosus root rot if there are many large true fir stumps (18 inches or greater in diameter) widely distributed in the stand. Fomes annosus can cause very severe losses in such stands, and these losses increase dramatically with time. If large, infected stumps already occur on a site, there is nothing short of their physical removal that will prevent spread of the disease into nearby true firs.

(2) Strongly consider stump treatment for F. annosus control during any harvest entries in stands where continued true fir management is planned. Apply sodium borate (borax) evenly to surfaces of all true fir stumps 18 inches or greater in diameter within 48 hours of cutting. Borax treatment prevents infection of newly created stumps by F. annosus spores. It does not affect the pathogen in already-colonized stumps. Thus, though stump treatment may be worthwhile in any true fir stand, it will have the greatest benefits when used in previously-unentered stands and in stands with few large true fir stumps not widely distributed across the unit. Stump treatment is not necessary if a site is to be regenerated with species other than true firs.

(3) Evaluate true fir stands under consideration for management activities in the northern part of the Ochoco National Forest for occurrence of laminated root rot. This disease also can cause devastating losses. Where laminated root rot occurs, do not manage true fir or Douglas-fir within detectable infection centers or a 50-foot buffer around each in subsequent rotations. Favor adapted tree species that are resistant (ponderosa pine), tolerant (lodgepole and western white pine), or intermediately susceptible (western larch and Engelmann spruce) to the disease.

(4) Where Armillaria root rot is severe and causes large disease centers in true fir stands, as it does in some areas on the Snow Mountain District of the Ochoco National Forest, favor pines (first choice) or Douglas-fir (second choice) in future rotations.

(5) Minimize wounding of crop trees and site disruption in true fir stands. The true firs are very prone to injury and sensitive to disturbance. Fir engraver beetles, stem decay fungi, annosus root rot, and Armillaria root rot all are favored on injured or weakened trees.

(6) When deciding whether or not to manage a true fir understory left after an overstory removal, consider the current condition of the fir and its potential for developing unacceptable amounts of stem decay. Employ the equations developed by Filip et al to predict infection levels and project amount of decay. Do not attempt to manage high-risk understories.

(7) True firs should be managed on relatively short rotations (120 years or less). In determining whether or not to manage a true fir understory left after a true fir overstory is removed, ages of both understory and overstory should be considered. Understories that have been suppressed for 50 years or more are usually not good risks for management. If overstory trees being harvested are over 120 years old, risk of the understory trees having been exposed to infection by stem decay fungi and Armillaria root rot is considerably greater than would be the case if younger overstory trees were involved.

(8) When considering true fir prescriptions, remember that, in general, selective harvesting of true fir stands contributes to a much greater likelihood of future pest problems than regeneration harvesting. Salvage logging in root-diseased stands begets more salvaging by favoring increased infection and higher inoculum potential.

In addition to the specific management recommendations listed for true fir stands on the Ochoco and Fremont National Forests, we suggest that true fir stands in other East Side forests also be evaluated for magnitude of pest problems and possible relationships between loss and stand type. Special management practices may be necessary in other areas where these valuable but pest-prone species occur.

Fig. 1 Typical stain caused by Fomes annosus in white fir root. Note reddish-brown color and uneven margin.

Fig. 2 Typical advanced decay caused by Fomes annosus. Rot is white, stringy, or slightly laminated, and contains black flecks.

Fig. 3 Fomes annosus conks in center of old, hollow, white fir stump.

Fig. 4 Annosus root rot center in young white fir on the Fremont National Forest. Disease centers usually develop around an old, infected stump.

Fig. 5 Typical laminated decay caused by P. weirii on grand fir. Note how the wood separates readily along the growth rings and reddish, whiskery setal hyphae occur between the layers.

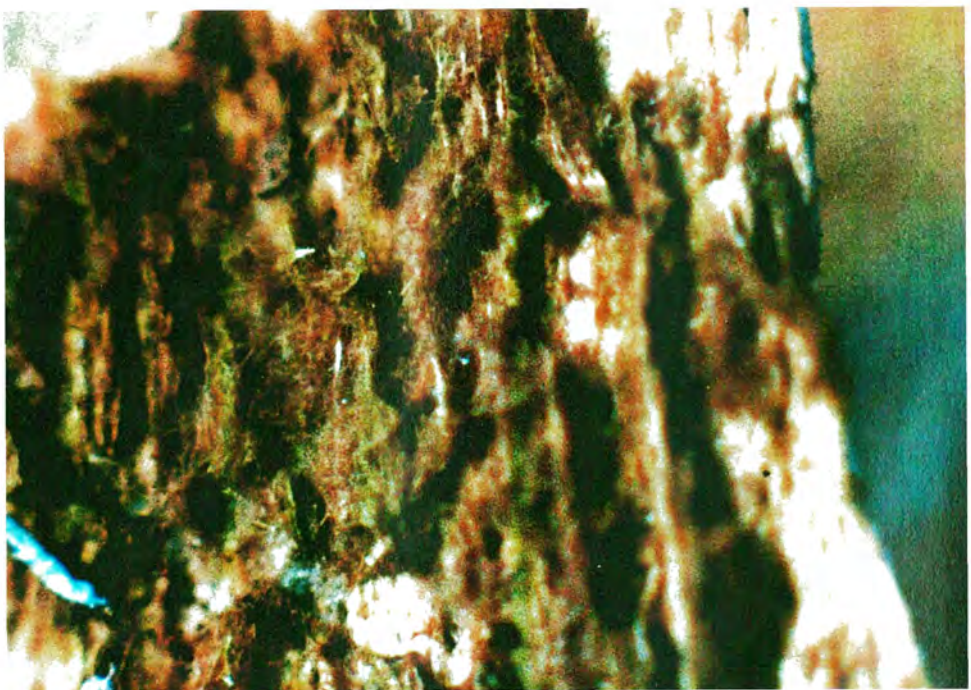

Fig. 6 Magnification (5X) of P. weirii setal hyphae. These structures are diagnostic for this pathogen.

Fig. 7 Typical "root ball" on grand fir resulting from destruction of the root system by P. weirii. Laminated decay and setal hyphae are readily evident in the old root stubs.

Fig. 8 Diagnostic white mycelial fan of A. mellea under bark of grand fir. Mycelium resembles a sheet of dried latex paint.

Fig. 9 Active Armillaria root rot center in grand fir on the Ochoco National Forest.

Fig. 10 Galleries of fir engraver beetles (S. ventralis) under bark of grand fir. These beetles frequently give the coup de grace to disease-weakene trees. The wide, shallow galleries in the upper left corner are caused by secondary flatheaded borers.

Fig. 11 Cross-section of white fir stem showing advanced decay caused by E. tinctorium, one of the most common and damaging stem decay fungi affecting true firs.

Fig. 12 Conks of E. tinctorium on grand fir. These fruiting bodies usually are not formed until a substantial decay column has developed.

Fig. 13. Old logging scar on white fir, typical of many trees in entered stands on the Ochoco and Fremont National Forests. Such scars are frequently activators of dormant Indian paint fungus infections or infection courts for other stem decay fungi.

Table 1: Equations for multiple regressions between photo-interpreted data and 100% ground cruise results for total mortality and true fir mortality in species composition/past management regime strata evaluated on the Ochoco and Fremont National Forests.

Actual Total Amount of Mortality = a + (b x interpreted no. dead true fir) + (c x interpreted no. dead pine) + (d x interpreted total amount of mortality).

| | True Fir Overstory | | | Pine Overstory | | |
|---|---|---|---|---|---|---|
| Values | Unentered | One Entry | Multiple Entries | Unentered | One Entry | Multiple Entries |
| a | -72.92 | 11.95 | 11.74 | -0.97 | 5.36 | 0.53 |
| b | 10.76 | 0.10 | -0.70 | 7.40 | 2.40 | 4.04 |
| c | 0.91 | -2.86 | -1.49 | -0.12 | -3.89 | -1.22 |
| d | 3.08 | 1.26 | 2.36 | 2.18 | 4.08 | 0.89 |
| $R^2$ | 0.66 | 0.24 | 0.27 | 0.96 | 0.75 | 0.83 |

Actual Amount of True Fir Mortality = a + (b x interpreted no. dead true fir) + (c x interpreted no. dead pine) + (d x interpreted total amount of mortality).

| | True Fir Overstory | | | Pine Overstory | | |
|---|---|---|---|---|---|---|
| Values | Unentered | One Entry | Multiple Entries | Unentered | One Entry | Multiple Entries |
| a | -32.39 | 9.79 | 8.19 | -0.29 | 1.24 | -3.12 |
| b | 0.04 | 0.85 | 1.06 | 2.78 | -1.89 | 0.39 |
| c | -2.76 | -0.49 | 0.37 | 0.19 | -3.50 | -2.40 |
| d | 5.05 | 0.08 | 0.75 | -0.11 | 3.44 | 3.75 |
| $R^2$ | 0.43 | 0.21 | 0.30 | 0.94 | 0.89 | 0.37 |

Table 2: Stocking, true fir mortality figures, and percentage of firs affected by pests in the species composition/past management regime strata evaluated on the Ochoco and Fremont National Forests.

| Forest & Stand Type | Mean Number Trees/Acre 6" DBH or Greater | Mean % of Total Stocking in True firs | Mean % of True Firs Dead | | Mean % true fir infected by: | | | | # | Mean % True fir infested by Scolytus ventralis # |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Stand Exam | Aerial Interpretation | Fomes annosus | Armillaria mellea | Phellinus weirii | Stem Decay fungi | Dwarf Mistletoe | |
| Ochoco NF | | | | | | | | | | |
| Pine Overstory | | | | | | | | | | |
| Unentered | 189 | 24 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| Entered Once | 142 | 23 | 6 | 6 | 2 | 0 | 0 | 5 | 0 | 6 |
| Multiple Ent. | 86 | 49 | 1 | 2 | 0 | 0 | 0 | 4 | 0 | T* |
| Fir Overstory | | | | | | | | | | |
| Unentered | 238 | 68 | 23 | 20 | 0 | 4 | 16 | 36 | T* | 10 |
| Entered Once | 102 | 78 | 15 | 12 x | 1 | 2 | 0 | 59 | 2 | 3 |
| Multiple Ent. | 80 | 50 | 9 | 6 x | 5 | 0 | 0 | 43 | 0 | 4 |
| Fremont NF | | | | | | | | | | |
| Pine Overstory | | | | | | | | | | |
| Unentered | 193 | 37 | 0 | 1 | 0 | 0 | 0 | 21 | 0 | 0 |
| Entered Once | 110 | 40 | 5 | 3 | 1 | T * | 0 | 13 | 0 | 1 |
| Multiple Ent. | 227 | 36 | 14 | 16 | 0 | 0 | 0 | 20 | 0 | 0 |
| Fir Overstory | | | | | | | | | | |
| Unentered | 249 | 31 | 2 | 1 | T * | 1 | 0 | 58 | T * | 1 |
| Entered Once | 134 | 80 | 6 | 4 x | 2 | 3 | 0 | 58 | 0 | 1 |
| Multiple Ent. | 119 | 78 | 23 | 13 x | 17 | T * | 0 | 37 | T * | 3 |

* T = Trace amount (less than 0.5%) # Based on stand exams x Regressions showed low $R^2$ values

Table 3: Mean percent of true fir volume decayed in stands surveyed on the Ochoco and Fremont National Forests (based on stem decay equations Filip et al 1983).

| Forest and Stand Type | Percent Board Foot Volume Decayed |
|---|---|
| Ochoco National Forest | |
| Pine Overstory | |
| Unentered | 0.0 |
| Entered Once | 0.7 |
| Multiple Entries | 2.2 |
| Fir Overstory | |
| Unentered | 2.7 |
| Entered Once | 21.4 |
| Multiple Entries | 3.3 |
| Fremont National Forest | |
| Pine Overstory | |
| Unentered | 0.5 |
| Entered Once | 19.8 |
| Multiple Entries | 3.0 |
| Fir Overstory | |
| Unentered | 22.7 |
| Entered Once | 17.0 |
| Multiple Entries | 8.9 |

# APPENDIX A

## Cumulative Stand Tables by National Forest, Overstory, and Harvest Entry Category

Table A1: Mean number of trees/acre for sampled stands on the Ochoco National Forest with pine overstories and no harvest entries.

| DBH Class (inches) | Ponderosa Pine | | | | Grand Fir/White Fir | | Douglas-fir | | | | Western Larch | | Lodgepole Pine | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Alive | Dead | | | Alive | Dead | Alive | | Dead | | Alive | Dead | Alive | Dead |
| | Healthy | Unknown | Western Pine Beetle | Mountain Pine Beetle | Healthy | Unknown | Healthy | Mistletoe Infected | Unknown | Mistletoe | Healthy | Windthrown | Healthy | Mountain Pine Beetle |
| Less than 6 | 146.7 | 60.0 * | | | 146.7 | 6.7 * | 250.0 | 36.7 | 3.3 * | | 13.3 | 6.7 | | 6.6 |
| 6 | | | | 6.8 | 20.4 | | 13.6 | 6.8 | | | 13.6 | | 6.8 | 13.6 |
| 8 | | | | 3.8 | 15.3 | | 11.5 | 7.6 | | | 7.6 | | | 22.9 |
| 10 | 9.8 | | | 4.9 | 7.3 | | 4.9 | 2.4 | | | 4.9 | | 2.4 | 7.2 |
| 12 | 6.8 | | 1.7 | | | | 3.4 | | | | 3.4 | | | 1.7 |
| 14 | 3.7 | | | | 1.2 | | 1.2 | 0.6 | | | | | 1.2 | |
| 16 | 5.7 | | | | | | | | | | 0.9 | | | |
| 18 | 5.3 | | | | | | 0.7 | 0.8 | | | | | | |
| 20 | 3.1 | | 0.6 | | | | 1.2 | | | | | | | |
| 22 | 1.0 | | | | | | | 0.6 | | | | | | |
| 24 | 3.4 | | 0.4 | | | | | | 0.4 | | | | | |
| 26 | 2.5 | | | | | | 0.4 | 0.2 | | | | | | |
| 28 | 2.2 | | 0.3 | | | | | | | | | | | |
| 30 | 1.6 | | | | | | | | | 0.5 | | | | |
| 32 | 2.1 | | | | | | | | | 0.2 | | | | |
| 34 | 1.1 | | | | 0.2 | | | | | 0.2 | | | | |
| 36 | 0.4 | | | | 0.2 | | | | | 0.2 | | | | |
| 38 | 0.3 | | | | | | | | | 0.2 | | | | |
| 40 | 0.8 | | | | | | | | | | | | | |
| 42 | 0.3 | | | | | | | | | | | | | |
| 44 | 0.1 | | | | | | | | | | | | | |
| Total over 6 | 50.2 | 0.0 | 3.0 | 15.5 | 44.6 | 0.0 | 36.9 | 19.2 | 0.4 | 1.3 | 30.4 | 0.0 | 10.5 | 35.4 |

* Probable cause was suppression

Table A2: Mean number of trees/acre for sampled stands on the Ochoco National Forest with pine overstories and one harvest entry prior to 1978.

| DBH Class (inches) | Ponderosa Pine | | | | | | White Fir | | | Douglas-fir |
|---|---|---|---|---|---|---|---|---|---|---|
| | Live | | Dead | | | | Live | | Dead | Live |
| | Healthy | Mistletoe Infected | Unknown | Fire | Mountain Pine Beetle | Western Pine Beetle | Healthy | F. annosus Infected | Fir Engraver | Healthy |
| Less than 6 | 148.8 | 5.0 | 10.0 * | 5.0 | 1.7 | | 35.0 | | | 15.0 |
| 6 | 33.9 | | | | | | 10.2 | | | |
| 8 | 21.0 | | | | | | 11.5 | | 1.9 | |
| 10 | 14.7 | | | | | | | | | |
| 12 | 6.8 | | | | | | 5.1 | | | 1.7 |
| 14 | 6.9 | 0.6 | | | | | 1.2 | 0.6 | | 0.6 |
| 16 | 4.8 | | | | | | 0.5 | | | |
| 18 | 3.4 | | | | | | 0.4 | | | |
| 20 | 2.1 | | | | | | 0.3 | | | |
| 22 | 1.8 | | | | | 0.5 | | | | |
| 24 | 0.8 | 0.4 | | | | | 0.4 | | | |
| 26 | 0.7 | | | | | | | | | |
| 28 | 1.2 | 0.2 | | | 0.2 | | | | | |
| 30 | 1.1 | 0.1 | | | | | | | | |
| 32 | 0.7 | | | | | | | | | |
| 34 | 0.3 | | | | | | | | | |
| 36 | 0.4 | | | | | 0.1 | | | | |
| 38 | 0.2 | | | | | | | | | |
| 40 | 0.1 | | | | | 0.1 | | | | |
| 42 | | | | | | | | | | |
| 44 | 0.1 | | | | | | | | | |
| 46 | | | | | | | | | | |
| 48 | | | | | | | | | | |
| 50 | | | | | | | | | | |
| 52 | | | | | | | | | | |
| Total over 6 | 103.4 | 1.3 | 0.0 | 0.0 | 0.2 | 0.7 | 29.6 | 0.6 | 1.9 | 2.3 |

* Probable cause was suppression

Table A3. Mean number of trees/acre for sampled stands on the Ochoco National Forest with pine overstories and multiple harvest entries prior to 1978.

| DBH Class (inches) | Ponderosa Pine Live Healthy | Ponderosa Pine Live Mistletoe Infected | Ponderosa Pine Dead Unknown | Grand Fir/White Fir Live Healthy | Grand Fir/White Fir Dead Unknown | Grand Fir/White Fir Dead E. tinctorium & Break | Grand Fir/White Fir Dead E. tinctorium Fir Engraver | Douglas-Fir Live Healthy | Lodgepole Pine Live Healthy |
|---|---|---|---|---|---|---|---|---|---|
| Less than 6 | 146.0 | 10.0 | 4.0 * | 80.0 | 6.0 * | | | 4.0 | 60.0 |
| 6 | 4.1 | | | 20.4 | | | | 4.1 | |
| 8 | 9.2 | 2.3 | | 2.3 | | | | | |
| 10 | 4.4 | | | 8.8 | | | | 1.5 | |
| 12 | 2.0 | | | 3.1 | | | | 2.0 | |
| 14 | 2.2 | | | 1.5 | | | | 0.7 | |
| 16 | 1.7 | 0.6 | | 3.4 | | | | | |
| 18 | 0.9 | 1.4 | | 1.4 | | | | | |
| 20 | 1.1 | 0.4 | | 0.4 | | | | | |
| 22 | 0.6 | 0.3 | | 0.3 | | | | | |
| 24 | 0.5 | 1.0 | | | | | | | |
| 26 | | 0.6 | | | | 0.2 | | | |
| 28 | 0.2 | 0.2 | | | | | | | |
| 30 | 0.5 | | | | | | | | |
| 32 | 0.3 | 0.6 | | | | 0.1 | | | |
| 34 | 0.1 | 0.4 | | | | | | | |
| 36 | 0.1 | | | | | | | | |
| 38 | | | | | | | | | |
| 40 | | | | | | | | | |
| 42 | 0.1 | | | | | | | | |
| 46 | | | | | | | | | |
| 48 | | | | | | | 0.1 | | |
| 50 | | | | | | | | | |
| Total over 6 | 27.5 | 8.2 | 0.0 | 41.5 | 0.0 | 0.3 | 0.1 | 8.3 | 0.0 |

* Probable cause was suppression

Table 44 Mean number of trees/acre for sampled stands on the Ochoco National Forest with true fir in the overstories and no harvest entries

| DBH Class (Inches) | Ponderosa Pine: Live Healthy | Grand Fir/White Fir: Live Healthy | Grand Fir/White Fir: Live Dwarfmistletoe Combs | Grand Fir/White Fir: Live Mistletoe Infected | Grand Fir/White Fir: Dead Unknown | Grand Fir/White Fir: Dead A. mellea | Grand Fir/White Fir: Dead A. mellea & Fir Engravers | Grand Fir/White Fir: Dead P. weirii | Grand Fir/White Fir: Dead P. weirii & Fir Engravers | Grand Fir/White Fir: Dead Fir Engravers | Grand Fir/White Fir: Dead E. tinct & Brook | Douglas-fir: Live Healthy | Douglas-fir: Live Mistletoe Infected | Douglas-fir: Live P. weirii Infected | Douglas-fir: Dead P. weirii | Douglas-fir: Dead P. weirii and Douglas-fir beetle | Douglas-fir: Dead A. mellea | J. Western Larch: Live Healthy | J. Western Larch: Live Mistletoe Infected | J. Western Larch: Dead Unknown | J. Western Larch: Dead Mistletoe | J. Western Larch: Dead P. weirii | Lodgepole Pine: Live Healthy | Lodgepole Pine: Dead Unk | Lodgepole Pine: Dead P. weirii | Engelmann Spruce: Live Healthy | Engelmann Spruce: Dead Unknown |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Less than 6 | | 945.7 | | | 125.7 a | | | 16.3 | | | | | | | | | | | | | | | | | | | |
| 6 | | 40.7 | | | | 5.1 | | 5.1 | | | | | | | | | | | | | | | | 45.7 | 85.7a | | 76.3 | 28.8a |
| 8 | | 28.6 | | | | | | 2.9 | 5.7 | | | | | | | | | | | | | | | 10.2 | | | | |
| 10 | | 25.7 | | | | | | | 1.8 | | | 1.8 | | | | | | | | | | | | 2.9 | | | 2.9 | |
| 12 | | 12.7 | | | | | | | 2.5 | 1.3 | | 1.3 | | | | | 1.3 | 1.3 | | | 3.6 | | | 9.2 | | | 1.8 | |
| 14 | | 2.8 | | | 0.9 | | | 1.9 | | | | | | | | 0.9 | | | | | 2.5 | | | 8.9 | | | | |
| 16 | 1.6 | 2.5 | | | | | | | 2.1 | | 0.7 | | | | 0.7 | | | | | | 1.9 | | | | | | 0.9 | |
| 18 | | 1.1 | | | 0.6 | 1.1 | 0.6 | 1.1 | 1.1 | | | 1.1 | | | | 0.6 | | | | | 2.9 | | | | | | 1.6 | |
| 20 | 0.5 | 2.3 | 0.5 | | | | | | | | | 0.9 | 0.5 | | 0.5 | | | | 0.6 | | 1.7 | 2.3 | 0.6 | | 1.1 | | |
| 22 | 0.6 | 1.0 | | | | | | | | | | | | 0.7 | 0.6 | | | | | | 0.9 | | | | | | |
| 24 | | 1.9 | 0.3 | | | 0.3 | | | | | | 0.5 | 0.6 | | | | | | 0.6 | | 0.6 | | | | | | |
| 26 | | 1.6 | | | 0.6 | | | 0.3 | | | | | | | | | | | | | | | | | | | 0.3 | |
| 28 | | 1.0 | 0.5 | | | | | 0.9 | 0.5 | | | | | | | | | | | | | | | | | | | |
| 30 | | | | | | | | 0.2 | | | | | 0.2 | | | | | | | | | | | | | | | |
| 32 | | 0.2 | | 0.2 | | | | | | | | | 0.6 | | | | | | | 0.6 | | | | | | | | |
| 36 | | | | | | | | | | | 0.2 | | | | 0.2 | | | | | | | | | | | | | |
| Total over 6 | 2.1 | 123.2 | 1.3 | 0.2 | 2.1 | 6.5 | 0.6 | 12.8 | 13.1 | 1.3 | 0.9 | 5.7 | 1.7 | 0.7 | 1.8 | 1.5 | 1.3 | 1.3 | 1.0 | 0.6 | 13.9 | 2.3 | 11.7 | 8.0 | 1.1 | 7.9 | 0.0 |

a Probable cause was suppression

Table A5: Mean number of trees/acre for sampled stands on the Ochoco National Forest with true fir in the overstories and one harvest entry prior to 1978.

| DBH Class (inches) | Ponderosa Pine - Live | Grand Fir/White Fir | | | | | | | | | | | | Western Larch | | | Douglas-fir | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Live | | | | Dead | | | | | | | | Live | | Dead | Live | | Dead |
| | | | | | | | | | | | | | | | Mistletoe | | | Mistletoe | |
| | Healthy | Healthy | E.tinct. Conks | Mistletoe Infected | F. annosus Infected | Unknown | Mechan. Damage | F. annosus | F.annosus | A.mellea Fir engraver | Fir engraver | E.tinc. & Break | Healthy | Infected | Mistle-toe | Healthy | Infected | Unknown |
| Less than 6 | 5.0 | 530.0 | | | | 6.75 * | | 5.0 | | | | | 12.5 | | | 17.5 | | |
| 6 | | 15.3 | | | | | 5.1 | | | | | | | | | | | |
| 8 | | 11.5 | | | | | | | | | | | | | | 5.7 | | |
| 10 | | 16.5 | | | | | | | | | | | | | | 3.7 | | |
| 12 | | 3.8 | | | | | | | | | | | | | | | 1.3 | |
| 14 | | 2.8 | | | | | | | | 0.9 | | | | | | | | |
| 16 | 2.1 | 4.3 | | | | 0.7 | | | | | | | 0.7 | | | | | |
| 18 | | 1.1 | | 0.6 | | | | | | | | 1.7 | | | 0.6 | | | |
| 20 | 0.5 | 1.8 | 0.5 | | | | | | | 0.5 | | | | | | | | |
| 22 | 0.4 | 1.5 | 0.8 | 0.8 | | | | | | | | | | 0.4 | | | 0.4 | |
| 24 | 0.6 | 0.6 | 0.3 | | | | | | | | | | | | | | | |
| 26 | | | 0.3 | 0.3 | | | 0.3 | | | | | 0.3 | | | | | | 0.3 |
| 28 | 0.7 | 0.2 | 0.5 | 0.2 | 0.2 | 0.2 | | | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | | | | | 0.5 |
| 30 | 0.4 | 0.2 | 0.6 | | | | | 0.2 | | | | 0.4 | | | | | | |
| 32 | 0.2 | 0.2 | 0.5 | | | | | | | | | | | | | | 0.2 | |
| 34 | 0.5 | | 0.2 | | | | | | | 0.2 | | | | | | 0.2 | 0.2 | |
| 36 | | | 0.7 | | | | | | | | | 0.3 | | | | | | |
| 38 | 0.5 | | 0.4 | | | | | | | | | | | | | | | |
| 40 | 0.4 | | 0.2 | | | | | | | | | 0.1 | | | | | | |
| 42 | | | 0.2 | | | | | | | 0.1 | | | | | | | | |
| 44 | | | | | | | | | | | | | | | | | | |
| 46 | | | 0.3 | | | | | | | | | 0.1 | | | | | | |
| 48 | | | | | | | | | | | | | | | | | | |
| 50 | | | 0.1 | | | | | | | | | | | | | | | 0.1 |
| Total over 6 | 8.4 | 59.9 | 5.7 | 1.9 | 0.2 | 0.9 | 5.4 | 0.2 | 0.2 | 1.9 | 0.2 | 3.1 | 0.9 | 0.4 | 0.6 | 9.6 | 2.1 | 0.9 |

* Probable cause was suppression

Table A6: Mean number of trees/acre for sampled stands on the Ochoco National Forest with true fir in the overstories and multiple harvest entries.

| DBH Class (inches) | Ponderosa Pine | | | | | Grand Fir/White Fir | | | | | | Douglas-fir | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Live | | Dead | | | Live | Dead | | | | | Live | | Dead |
| | Healthy | Mistletoe Infected | Unknown | Mountain Pine Beetle | Western Pine Beetle | Healthy | E.tinc. Conks | Unknown | F. annosus | F.annosus & Fir Engraver | E.tinct. & Broken | Healthy | Mistletoe Infected | Mistletoe |
| Less than 6 | 198.3 | | 11.7 * | 1.7 | | 198.3 | | 15.0 * | 6.7 | | | 16.7 | | |
| 6 | 17.0 | | | | | 3.4 | | | | | | | | |
| 8 | | | | | | 5.7 | | | | | | | | |
| 10 | 4.9 | 1.2 | | | | 12.2 | | | | | 0.8 | | | |
| 12 | | | | | | 4.2 | | | | 0.8 | | 0.8 | | 1.2 |
| 14 | 0.6 | 0.6 | | | | 6.9 | | | 0.6 | 0.6 | | 1.9 | | |
| 16 | 0.5 | | | | | 1.4 | 0.5 | | | | | | | |
| 18 | 0.7 | | | | | 0.7 | 0.4 | | | | | 0.4 | | |
| 20 | 0.6 | | | | | | | | | | | 0.3 | | |
| 22 | | 0.2 | | | | 0.2 | | | | | | | 0.2 | |
| 24 | 1.5 | | | | | | | | | | 0.2 | 0.2 | | |
| 26 | 0.9 | 0.2 | | | | | | | | | | | | |
| 28 | 1.2 | 0.2 | | | | | 0.2 | | | | 0.2 | 0.2 | | |
| 30 | 1.4 | 0.3 | | | | | | | | | 0.3 | | | |
| 32 | 0.8 | | | | | | | | | | | | | |
| 34 | 0.4 | 0.1 | | | | | 0.2 | | | | 0.1 | 0.1 | | |
| 36 | 0.2 | 0.1 | | | | | | | | | | | | |
| 38 | 0.3 | 0.1 | | | 0.1 | | | | | | | | | |
| 40 | 0.1 | | | | | | | | 0.1 | | | | | |
| 42 | | | | | | | | | | | | | | |
| 44 | | | | | | | | | | | | | | |
| 46 | 0.1 | | | | | | | | | | | | | |
| Total over 6 | 31.3 | 3.0 | 0.0 | 0.0 | 0.1 | 34.9 | 1.2 | 0.0 | 7.4 | 1.4 | 1.6 | 3.9 | 0.2 | 1.2 |

* Probable cause was suppression

Table A7: Mean number of trees/acre for sampled stands on the Fremont National Forest with pine overstories and no harvest entries.

| DBH Class (inches) | Ponderosa Pine | | | | | White fir | | Incense Cedar | Lodgepole Pine |
|---|---|---|---|---|---|---|---|---|---|
| | Live | | Dead | | | Live | Dead | Live | Live |
| | Healthy | Mistletoe Infected | Unknown | Mountain Pine Beetle | Western Pine Beetle | Healthy | Unknown | Healthy | Healthy |
| Less than 6 | 530.0 | 20.0 | 40.0 * | | | 113.3 | 3.3* | 26.7 | 3.3 |
| 6 | 6.8 | | | 13.6 | | 13.6 | | 6.8 | |
| 8 | 7.6 | | | | | 11.5 | | | |
| 10 | 14.7 | | | | | 22.0 | | | |
| 12 | 13.6 | | | 5.1 | | 13.6 | | 1.7 | |
| 14 | 10.0 | 1.2 | | 1.2 | | 7.5 | | 2.5 | |
| 16 | 6.7 | | | | | 0.9 | | | |
| 18 | 6.7 | | | | 0.7 | 0.7 | | | |
| 20 | 0.6 | | | 0.6 | | | | | |
| 22 | 4.5 | | | 0.5 | 0.6 | 0.5 | | | |
| 24 | 3.0 | 1.3 | | | 0.8 | 0.4 | | | |
| 26 | 1.4 | 1.8 | | | 0.7 | | | | |
| 28 | 1.6 | | | | 0.3 | | | | |
| 30 | 1.6 | 0.5 | | 0.2 | | | | | |
| 32 | 1.2 | | | | | | | | |
| 34 | 0.2 | 0.2 | | | | | | | |
| 36 | 0.2 | | | | | | | | |
| 38 | 0.3 | | | | | | | | |
| 40 | 0.5 | | | | | | | | |
| 42 | | | | | | | | | |
| 44 | | | | | 0.1 | | | | |
| Total over 6 | 81.2 | 5.1 | 0.0 | 21.2 | 3.2 | 70.7 | 0.0 | 11.0 | 0.0 |

* Probable cause was suppression

Table A8: Mean number of trees/acre for sampled stands on the Fremont National Forest with pine overstories and one harvest entry prior to 1978.

| DBH Class (inches) | Ponderosa Pine | | | | White fir | | | | | Whitebark Pine | Incense Cedar | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Live | | Dead | | Live | | Dead | | | Live | Live | Dead |
| | Healthy | Mistletoe Infected | Mountain Pine Beetle | Western Pine Beetle | Healthy | F.annosus Infected | Unknown | F.annosus & Fir Engraver | A.mellea & Fir Engraver | Healthy | Healthy | Unknown |
| Less than 6 | 138.3 | | 1.7 | | 168.3 | | 1.7 * | | | 3.3 | 40.0 | |
| 6 | 20.4 | | | | 17.0 | | | | | | | |
| 8 | 3.8 | | | | 7.6 | | | | | 1.2 | 3.8 | |
| 10 | 7.3 | | | | 8.6 | | | | | | 1.2 | |
| 12 | 2.5 | | | | 1.7 | | 1.8 | | | | | |
| 14 | 4.4 | | | | 1.9 | | | | | | | |
| 16 | 2.4 | | | | 3.3 | | | | | | 1.0 | |
| 18 | 3.4 | | | | 1.1 | | | | | | | |
| 20 | 3.4 | | | | | | | | | | 0.6 | |
| 22 | 2.8 | | | | | | | | | | 0.2 | |
| 24 | 0.6 | 0.2 | | | | | | | 0.2 | | 0.2 | |
| 26 | 0.9 | 0.2 | | | 0.2 | | 0.2 | | | | 0.4 | 0.2 |
| 28 | 0.8 | | | | 0.3 | | | | | | 0.5 | |
| 30 | 0.4 | | | | 0.1 | | | | | | 0.1 | |
| 32 | 0.8 | | | 0.1 | | | | | | | 0.4 | |
| 34 | 0.5 | | | | 0.1 | | | 0.1 | | | 0.1 | |
| 36 | 0.2 | | | | | 0.1 | | | | | 0.2 | |
| 38 | | | | | 0.1 | | | | | | | |
| 40 | | | | | | | | | | | | |
| 42 | | 0.1 | | | 0.1 | | | | | | 0.1 | |
| 44 | | | | | | | | | | | | |
| 46 | | | | | | | | | | | 0.1 | |
| Total over 6 | 54.6 | 0.5 | 0.0 | 0.1 | 42.1 | 0.1 | 2.0 | 0.1 | 0.2 | 1.2 | 8.9 | 0.2 |

* Probable cause was suppression

Table A9: Mean number of trees/acre for sampled stands on the Fremont National Forest with pine overstories and multiple harvest entries prior to 1978.

| DBH Class (inches) | Ponderosa Pine | | | White fir | |
|---|---|---|---|---|---|
| | Live | Dead | | Live | Dead |
| | Healthy | Mech. Damage | Unknown | Healthy | Mech. Damage |
| Less than 6 | 50.0 | | 40.0 * | 110.0 | |
| 6 | 20.4 | 20.4 | | 20.4 | |
| 8 | | 22.9 | | 22.9 | 11.5 |
| 10 | 14.7 | | | 7.3 | |
| 12 | 15.3 | | | 5.1 | |
| 14 | 22.4 | | | 7.5 | |
| 16 | 8.6 | | | 5.7 | |
| 18 | 9.0 | | | | |
| 20 | 5.5 | | | | |
| 22 | 3.0 | | | | |
| 24 | 1.3 | | | | |
| 26 | | | | | |
| 28 | | | | 0.9 | |
| 30 | 0.8 | | | | |
| 32 | 0.7 | | | | |
| 34 | 0.6 | | | | |
| 36 | | | | | |
| 38 | | | | | |
| 40 | 0.5 | | | | |
| Total over 6 | 102.8 | 43.3 | 0.0 | 69.9 | 11.5 |

* Probable cause was suppression

Table A10: Mean number of trees/acre for sampled stands on the Fremont National Forest with true fir in the overstory and no harvest entries.

| DBH Class (inches) | Ponderosa Pine | | | White Fir | | | | | | | Western White Pine | | | Lodgepole Pine | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Live | Dead | | Live # | | Dead | | | | | Live | Dead | | Live | | Dead | | | |
| | Healthy | Wind | MPB | Healthy | E.tino. Conks | Unknown | F. annosus | A.mellea & Fir engraver | E.tino. & Fir engraver | A.m., E.t., & Fir engravers | Fir engraver | Healthy | Unknown | MPB | Healthy | Mistletoe Infected | Unknown | MPB | Mistle-toe | Wind |
| Less than 6 | 31.2 | | | 767.5 | | 31.2* | | | | | | 115.0 | 2.5* | | 222.5 | 5.0 | 12.5* | | | |
| 6 | 7.7 | 2.5 | | 28.0 | | | | | | | | 2.6 | | | 40.1 | 2.5 | 2.5 | | | 2.5 |
| 8 | 4.3 | | | 14.3 | | | | | | | | | | | 32.9 | 2.9 | | 1.4 | 1.4 | |
| 10 | 3.7 | | | 10.1 | | | | | | | | | | | 13.7 | 0.9 | | | 0.9 | 0.9 |
| 12 | 1.9 | | 0.6 | 2.5 | | | | | | | | 1.3 | | | 10.2 | 3.8 | | | | |
| 14 | 0.5 | | | 4.2 | | | | | | | | 1.9 | | | 7.0 | 1.4 | 0.5 | 0.5 | | |
| 16 | 0.4 | | | 2.1 | | | | | | | | 0.4 | | 0.4 | 3.4 | 0.4 | | | | |
| 18 | 0.8 | | | 3.4 | | | | | | | 0.3 | 0.6 | | | 1.1 | | | | | |
| 20 | | | | 0.9 | | | | | | | | 0.5 | | | 0.9 | | | | | |
| 22 | | | | 1.5 | | | | | | | | 0.9 | | | 0.4 | | | | | |
| 24 | 0.3 | | 0.2 | 0.9 | 0.5 | | | | | | | 0.2 | | 0.2 | | | | | | |
| 26 | 0.4 | | | 1.4 | | | 0.1 | | 0.1 | | | 0.5 | | 0.2 | | | | | | |
| 28 | 0.1 | | | 0.8 | 0.7 | | | 0.1 | | | | 0.1 | | | 0.1 | | | | | |
| 30 | 0.3 | | 0.2 | 1.5 | 0.2 | | | | | 0.3 | | 0.4 | | | | | | | | |
| 32 | 0.5 | | | 0.6 | | | | | | | | | | | | | | | | |
| 34 | 0.2 | | 0.2 | 0.4 | 0.1 | | | | | 0.1 | | 0.3 | | | | | | | | |
| 36 | 0.1 | | | 0.4 | 0.1 | | | | | 0.1 | | 0.1 | | | | | | | | |
| 38 | 0.1 | | | 0.4 | 0.1 | | | | | | | 0.1 | | | | | | | | |
| 40 | 0.2 | | | | | 0.1 | | | | | | 0.1 | | 0.1 | | | | | | |
| 42 | 0.1 | | | 0.3 | | | | | | | | | | | | | | | | |
| 44 | 0.2 | | | | | | | | | | | | | | | | | | | |
| 46 | | | | 0.1 | | | | | | | | | | | | | | | | |
| Total over 6 | 21.9 | 2.5 | 1.2 | 74.0 | 1.7 | 0.1 | 0.1 | 0.1 | 0.1 | 0.5 | 0.3 | 9.9 | 0.0 | 0.9 | 110.6 | 11.9 | 3.0 | 1.9 | 2.3 | 3.4 |

# Live trees with dwarf mistletoe infections also occurred in this category but made up less than 0.05 trees/acre.
* Probable cause was suppression.

Table A11: Mean number of trees/acre for sampled stands on the Fremont National Forest with true firs in the overstories and one harvest entry prior to 1978.

| DBH Class (inches) | Ponderosa Pine | | White Fir | | | | | | | | Western White Pine | Lodgepole Pine | | Incense Cedar |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Live | Dead | Live | | Dead | | | | | | Live | Live | Dead | Live |
| | Healthy | Western Pine Beetle | Healthy | E.tinct. Conks | Unknown | F. annosus | F.annosus & A.mellea | A. mellea | A.mellea Fir engraver | E.tinct. & Break | Healthy | Healthy | Mtn.Pine Beetle | Healthy |
| Less than 6 | 40.0 | | 370.0 | | 8.3 * | 1.7 | | | | | 13.3 | 20.0 | | 1.7 |
| 6 | | | 37.3 | | | | | | | | | | | |
| 8 | 1.9 | | 28.6 | | | | | | | | | 1.9 | | |
| 10 | 2.4 | | 11.0 | | 1.2 # | | | | | | | 1.2 | | |
| 12 | 3.4 | | 4.2 | | | | 1.7 | | 0.8 | | 1.7 | 0.8 | 0.8 | |
| 14 | 1.2 | | 6.9 | | 0.6 | | | | | | | | | |
| 16 | 2.4 | | 3.8 | | 0.5 | | | | | | | 0.5 | | |
| 18 | | | 2.3 | | | | | | 0.4 | | 0.4 | | | |
| 20 | 1.5 | | 2.1 | | | | | | | | 0.9 | | | |
| 22 | 0.2 | | 0.8 | | | 0.2 | | | | | 0.2 | | | |
| 24 | 0.6 | | 1.3 | | 0.2 | | | | | | 0.2 | | | |
| 26 | 0.5 | 0.2 | 0.7 | | | | | 0.2 | 0.2 | 0.2 | | | | |
| 28 | 0.5 | | 0.5 | | 0.2 | | | 0.2 | | | 0.2 | | | |
| 30 | | 0.1 | 0.4 | | | | | | | | 0.3 | | | |
| 32 | 0.5 | | | 0.1 | | | | | | | | | | |
| 34 | 0.6 | | 0.3 | | | | | | | | | | | |
| 36 | 0.2 | | 0.1 | | | 0.1 | | | | | | | | |
| 38 | 0.1 | | | 0.2 | | | 0.1 | | | | 0.2 | | | |
| 40 | 0.7 | | | | | | | | | 0.1 | | | | |
| 42 | | | | | | | | | | | | | | |
| 44 | | | | | | | | | | | | | | |
| 46 | | | | | | | | | | | | | | |
| 48 | 0.1 | | | | | | | | | | | | | |
| Total over 6 | 17.1 | 0.3 | 100.4 | 0.3 | 2.7 | 0.3 | 1.8 | 0.4 | 1.4 | 0.3 | 4.1 | 4.4 | 0.8 | 0.0 |

* Probable cause was suppression
\# Probable cause was wind

Table A12: Mean number of trees/acre for sampled stands on the Fremont National Forest with true fir in the overstories and multiple harvest entries.

| DBH Class (inches) | Ponderosa Pine | | | | White Fir | | | | | | | | | Sugar Pine |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Live | Dead | | | Live | | | | Dead | | | | | Live |
| | Healthy | Unknown | MPB | WPB | Healthy | Mistletoe Infected | F.annosus Infected | E.tinc. Conks | Unknown | F. annosus | F.annosus & Fir engraver | F.anno.,A.mellea & Fir engraver | A.mellea & Fir engraver | Healthy |
| Less than 6 | 107.1 | 5.7* | | | 381.4 | 1.4 | | | 5.7* | 11.4 | | | | 1.4 |
| 6 | 5.8 | | | | 20.4 | | | | | | | | | |
| 8 | 6.5 | | | | 13.1 | | | | 1.6 | 3.3 | | | | |
| 10 | | | | | 8.4 | | | | | 3.1 | | | | |
| 12 | 2.9 | | | | 8.7 | | | | 0.7 | 2.1 | 1.5 | | | |
| 14 | 1.6 | | | | 2.1 | | | | | 0.5 | | | | |
| 16 | 1.2 | | | | 3.3 | | | | 0.4 | 0.8 | 0.4 | 0.4 | | |
| 18 | 1.0 | | | 0.3 | 2.6 | 0.3 | 0.3 | | | 0.6 | | | | |
| 20 | 0.5 | | | | 1.8 | | 0.3 | | 0.3 | 0.9 | | | | |
| 22 | 0.4 | | | | 0.9 | | 0.2 | | | 0.2 | 0.2 | | | |
| 24 | 0.9 | | | | 0.9 | | 0.2 | | | 0.4 | | | | |
| 26 | 0.9 | | | | 1.1 | | | | | | | | | |
| 28 | 0.7 | | | 0.1 | 0.4 | | | | | | | | | |
| 30 | 0.8 | | 0.1 | | 0.3 | | | | | | | | | |
| 32 | 0.1 | | | | 0.2 | | | | | | | | | |
| 34 | 0.3 | | | | | | | 0.1 | | | | | | |
| 36 | 0.2 | | | | | | 0.1 | | | 0.1 | | | | |
| 38 | | | | | | | | | | | | | | |
| 40 | 0.1 | | | | 0.1 | | | | | | | | | |
| 42 | | | | | | | | | | | | | 0.1 | 0.1 |
| Total over 6 | 24.2 | 0.0 | 0.1 | 0.4 | 64.4 | 0.3 | 1.1 | 0.1 | 3.0 | 10.0 | 2.1 | 0.4 | 0.1 | 0.1 |

*Probable cause was suppression.

72 43OSU 0220 FS